CSERIAC GATEWAY

In this issue:

Figure 1. The Cyberware WB-4 makes a whole-body scan of the CARD Lab's Matt Brunsman.

Earthquake in Anthropometry: The View from the Epicenter

Matt Brunsman
Hein Daanen
Patrick Files

E ven after discovering that the world was not flat, mapmakers were limited to representing our three-dimensional (3-D) world on a flat piece of paper. Their efforts were fine for small maps. On large maps, however, distortions appeared: continents were misshapen, enlarged, or shrunken. Like the earth, the human body is covered with ridges, hills, and valleys; it is anything but flat. Scientists attempting to "map" the body face the same difficulty with distortions that cartographers have with the earth. In engineering anthropometry, researchers measure a 3-D body with one-dimensional or two dimensional tools, construct flat representations in the form of flat patterns or drawings, and then translate the drawings back into 3-D forms to create the finished product.

Traditional anthropometry– measuring the body with calipers, tape measures, and other hand tool–

has been used for centuries to define sizes, ranges, and linear dimensions of the body, and to improve the fit of clothing, equipment, and workstations. This two-dimensional data is efficient and appropriate for many applications. For clothing and equipment items that must conform closely to the body's intricate topography, however, designers need precise information about body contours. Just as satellite photography expanded the boundaries of mapmaking, full-color, three-dimensional, high-resolution surface scanning is advancing the science of engineering anthropometry.

To take full advantage of 3-D data, researchers need tools to refine and analyze the scans. Traditional anthropometry is well established, so tools and techniques for applying 2-D data are completely validated, reliable, and easily understandable by many users. As a new technology, however, 3-D anthropometry is presently limited by the scarcity of tools and methods for using the data. The volume of data resulting from a scanning survey could be overwhelming, and not of much practical value, without techniques for managing the data. A new branch of image processing has emerged to address this need. Selective data reduction and automated post-processing methods now under development will allow designers to apply 3-D data to real-world design issues.

Advances in anthropometric technology will soon make it possible to use 3-D techniques in all phases of development, from design concept through end production. Apparel, automobiles, office furniture, sports equipment, prosthetics, and conceivably anything else people wear or use could soon be designed and produced completely in a 3-D environment. Customization of clothing and equipment will take on a whole new meaning, as designers not only customize the fit but also the 3-D location of different materials within a single item, and try items out on users before the items exist.

Scientists at the Computerized Anthropometric Research and Design (CARD) Laboratory of the Paul M. Fitts Human Engineering Division at Wright-Patterson Air Force Base are working to perfect 3-D anthropometric data collection. This article lists the advantages of 3-D scanning over traditional anthropometric data collection, discusses the challenges presented by scanning and how the CARD Lab is meeting those challenges, and describes the CARD Lab's plan for a major international survey scheduled to begin in 1997.

Background: Collaboration Produces Results

Since 1987, the CARD Lab has collaborated with Cyberware, Inc. to apply laser scanning technology to anthropometric research. The Lab's first laser scanner was the Cyberware 3-D Echo Digitizer Model 4020™, which has a scanning volume roughly the size of a human subject's head and neck. CARD Lab researchers used head scan data for helmet and oxygen mask fit tests; most recently, in a collaborative effort with hospitals in the Dayton area, researchers used head scan data in a project to improve the fit of therapeutic facial masks for burn victims (Kline & Whitestone, 1995; Robinette & Whitestone, 1992; Whitestone, 1993, 1994). To make full use of the scan data, the CARD Lab developed an extensive software tool-kit for visualization, analysis, manipulation, and application of the data to real-world design problems.

The CARD Lab's newest scanner, the Cyberware WB-4™, was the world's first whole-body laser scanner (see Fig. 1). CARD Lab researchers worked with Cyberware engineers to create specifications for a scanner that would meet the needs of anthropometric data collection. Extensive testing at the CARD Lab further enhanced the hardware and software capabilities of the WB-4.

Cyberware's WB-4 scanner has four scanning sensors, each containing a laser and two charge-coupled device cameras. The lasers project a flat plane of light onto the subject, and the cameras record the reflected laser light. The sensors scan the subject simultaneously, from top to bottom. The result is a full-color, 3-D, high-resolution image of the subject's surface.

Standing on the Shoulders of Traditional Methods: The Advantages of Scanning

With the WB-4 fully operational, researchers verified that scanning is both faster and less expensive than traditional data collection for large populations. The most important advantage of scanning, however, is the exceptional data that high-resolution surface scanning provides:

■ Scans reveal a great deal of information about the subject. Not only do scans provide traditional dimensions, but they also present detailed surface information about the subject, from which surface area, volume, and other measurements can be extracted. Scans also provide the 3-D location of dimensions relative to one another.

■ Scans can be stored in a database, and researchers can study them indefinitely, saving them for future research projects. Additional research on traditionally measured subjects would require finding the subjects and remeasuring them.

■ Scans can be imported into Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM) tools.

■ Scan data are easy to standardize, because the scans are not collected by human measurers. Repeatability of results must be strictly monitored with traditional anthropometric data, because each measurement technician has a unique measurement style. The scanner, however, scans every subject in the same manner.

Figure 2. "X-ray view" of flight suit fit.

■ Scan data can show the relationship between a subject and the equipment he or she wears, such as a helmet, glove, boot, or garment. A scan registration method developed at the CARD Lab reveals exactly how an equipment item fits the wearer. Figure 2 illustrates an "x-ray view" of a subject wearing a flight suit. Researchers and designers can quickly examine fit issues using this technique.

Applications for 3-D anthropometric data are almost limitless. Accurate 3-D anthropometric information can be used to design better fitting clothing, safer helmets, form-fitting chairs, and ergonomically designed automobiles, to name just a few examples. Soon, these digitized body images may also be imported into dynamic models or finite element code to examine kinematics, kinetics, and the human/equipment interface.

Improving Scan Quality: Experimenting for Standardization

Many factors can affect the quality of a 3-D whole body scan: clothing, scanner sensitivity, body position on the platform, and posture of the subject. To maximize the quality of the scans, CARD Lab researchers performed several short experiments to analyze these factors. Each factor was analyzed individually to observe its individual effects.

Colors: Lighter is better

Since human subjects have markedly different shades of skin, a basic research requirement determines the optimal scanner sensitivity for various skin tones. If the sensitivity is set too high, the scanner detects erroneous light information. High sensitivities should be avoided when scanning highly reflective objects, such as light skin tones. If the sensitivity is set too low, the scanner might miss some light information. The scanning sensitivity in the CARD Lab is set to provide consistently high-quality range and color data for all skin tones.

The well-dressed scan subject

Subjects are scanned wearing bathing suits or undergarments, so clothing requirements must also be determined. Several qualitative observations led CARD researchers to set standards for scanning clothing. The best clothing for scanning seems to be form-fitting, light-colored, and non-reflective. Dark colors, such as black or dark green, do not show up well in the scan at low scanning sensitivities, and shiny materials, such as spandex and nylon, reflect the laser light erratically, producing erroneous data points. Cotton materials, or cotton-polyester blends, are easily detected by the scanner. The standard scanning apparel for both men and women includes light-gray cotton biker shorts, and a gray sports bra for women. This clothing scans well, is inexpensive, and is available at most major clothing stores.

Examining Anthropometric Variables

Extracting anthropometric information–traditional 2-D measurements as well as spatial relationships–is the primary use of the whole-body scanner. CARD Lab researchers initially used 99 anthropometric variables to determine the relationship between traditional anthropometry postures and proposed scanning body postures. The list of variables was compiled through meetings with representatives from the automotive, clothing, and aerospace industries. Researchers used the list of recommended variables to determine how much information was provided by various subject postures.

Scanning Postures: Standing and Sitting

As in traditional anthropometric measurement, two main postures have been proposed for scanning: the standing posture and the sitting posture. Standardized scanning postures must meet several requirements. The scanning posture must:

■ Provide accurate comparisons to traditional anthropometric variables,

■ Be reproducible, so subjects are always scanned the same way,

■ Maximize the body surface coverage of the scan, and

■ Reveal all anthropometric body markers to ensure the markers are visible in the scan.

Traditional anthropometric sitting and standing postures are highly reproducible. However, several scanner limitations inhibit their effectiveness for 3-D scanning. For example, a traditional anthropometric standing posture requires subjects to hold their arms at their sides, while keeping their legs and ankles together. In this position it is impossible for the scanner to see highly shaded areas under the arms and between the legs. In addition, landmarks like the medial femeral epicondyles (inner side of the

knee) and the medial malleolus (inner side of the ankle) are hidden. Abduction of the arms and legs (holding them away from the body) increases the scanning area, but makes the scan less reproducible. Figure 3 shows how two repeated scans can result in different abduction angles in the arms.

The standard anthropometric sitting posture requires that the arms and legs form right angles at the elbow and knee joints. In this posture the subject's thighs and forearms are in the horizontal plane. Because the scanner projects laser light in a horizontal plane, horizontal surfaces do not reflect light back to the scanning sensors. In Figure 4, the lighter areas show where the scanner missed information on the upper thigh and forearm region. Without this information, it is difficult to measure thigh clearance or forearm

circumference.

To resolve this shading dilemma, CARD researchers proposed an additional seated scanning posture that maximizes body surface coverage and marker visibility (Fig. 5). This posture lowers the foot position to increase the knee angle. As a result, the thigh is no longer horizontal and can be seen by the cameras. The hands are held over the head in the mid-sagittal plane in what one subject called the "stick-em-up" position. Shading is eliminated, and this arm position is easily reproducible because of the right angle at the shoulder and elbow. Hard-to-see landmarks like the iliocristale (side of the hip) and medial humeral epicondyle (inner side of the elbow) are easily visible. The optimal scanning posture depends a great deal on the desired anthropometric information. The three postures in Figures 3, 4, and 5 are the proposed postures for the CAESAR study, an international 3-D scanning project described at the end of this article.

Reducing subject movement

Subject movement during the scan is another important concern, particularly for subjects in the standing posture. During the 17-second scan, subjects move or sway involuntarily, producing unwanted data artifacts. CARD researchers found that sway can be reduced by over 50% by placing a small, spring-loaded pointer on top of the subject's head (Fig. 6).
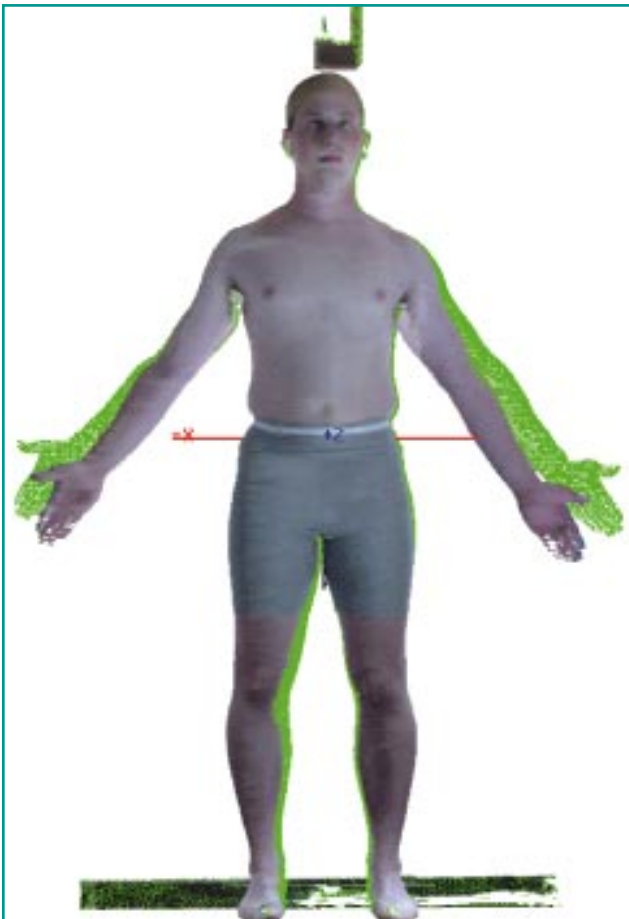

Figure 4. Missing data on horizontal surfaces.

Optimal Surface Coverage: Subject Orientation

After determining the best scanning postures, researchers investigated the best orientation of subjects on the scanning platform. The four sensors of the scanner are separated by 75- and 105-degree angles. The four heads are labeled zero, one, two, and three (counterclockwise). There are eight logical directions to face a subject: looking directly at any of the four scanning heads, facing between the scanning heads that are 75 degrees apart, and facing between the scanning heads that are 105 degrees apart.

To find the direction that provides the best scan, researchers made several scans of a mannequin positioned on the scanning platform facing in each of the eight possible directions. Researchers then used INTEGRATE, the CARD Lab-developed image visualization and manipulation software tool, to perform a surface-area calculation to
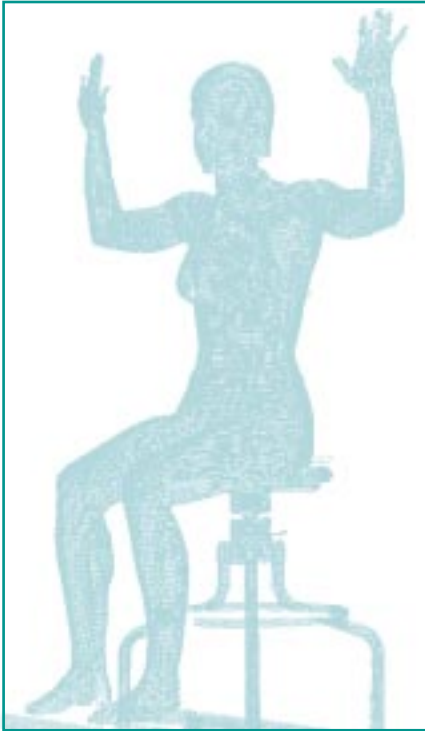

Figure 3. Poor repeatability of arm abduction angle.

Figure 5. Seated posture for maximizing body surface coverage.

measure the amount of information collected on each mannequin orientation (Burnsides, Files, & Whitestone, 1996). The optimal scanning position should minimize shading of body parts and optimize the visual angle of the sensors, thus resulting in the greatest surface area seen by the scanner. CARD researchers continue to study this question in an attempt to find the best position for both standing and seated scans.

The CARD Lab's to-do List: Scanning Challenges Still Ahead

While the CARD Lab has made significant progress on standardization issues in 3-D data collection, some important challenges remain on the horizon: developing advanced data-processing techniques, comparing traditional and 3-D anthropometric data, and protecting scan subjects' privacy.

Automated image data processing

The WB-4 produces enormous amounts of data which must be processed quickly and reliably. In small data collection efforts, research technicians can manually identify and label the landmarks in each scan. For a major anthropometric survey involving thousands of subjects, however, manually processing the scans would take years. Therefore, CARD researchers have developed beta-test versions of software tools that will interactively, semi-automatically, or automatically:

- Edit scan data,
- Reduce scan data,
- Format scan data,
- Segment scan data,
- Identify scanned landmarks,
- Label scanned landmarks, and
- Extract feature and measurement information.

Many of these tools are available in INTEGRATE 1.25, the latest version of INTEGRATE. A user's manual, complete with tutorials, is provided with the software. The CARD Lab is working to further refine these tools, many of which will be available in late 1997.

Comparing data

To use 3-D data to fullest advantage, researchers need to place it in context with the large resource of existing 2-D data. The CARD Lab is now conducting a detailed comparison of scan data and 2-D data to:

- Determine the feasibility and validity of taking traditional measurements from scan data. What traditional measurements can be taken from scans, and how accurate will those measurements be?
- Determine correlations between scan data and existing 2-D data. If measurements from scans differ from traditional measurements, do they differ consistently? Can researchers create equations (e.g., scanned stature + 1 mm = traditional stature) that will be true for every scan?
- Evaluate the reliability of scan data. Does the repeatability of measurements taken from scans differ from the repeatability of measurements in a traditional anthropometric survey? Which provides better repeatability, scanning or traditional methods?

Informal comparisons of the traditional and scanned data have been very encouraging. A thorough investigation of these comparison questions should allow designers to use scan data as confidently as they now use traditionally collected data.

Reassuring subjects

The WB-4 is most efficient when the scan subject wears very little clothing. While many people can be persuaded to participate in scanning surveys (perhaps because of the novelty of the technology), most people are justifiably concerned about the privacy of their data. The subject's name never appears on the scan itself, but because of the WB-4's high resolution, most subjects can be recognized from their scans. To protect subject identity, CARD researchers are experimenting with masking devices applied to the scans that will not destroy the data.

CAESAR: The International Survey

For many years, corporations that work with anthropometric data have called for an anthropometric database on civilian populations. (CSERIAC maintains and distributes a

Figure 6. Stabilizing pointer for minimizing sway.

comprehensive database of anthropometric data; see "The CSERIAC Anthropometric Data Files" on p. 7 of this issue for details.) In the 1970s the Mail Order Association of America (MOAA) worked with the National Bureau of Standards to initiate such a survey, and more recently, the Society of Automotive Engineers (SAE) and the American Society for Testing and Materials (ASTM) independently initiated data-gathering projects on civilians. The U.S. Department of Defense needs anthropometric data on civilians as a pending change in body size requirements for entry into military service will allow both smaller and larger people to serve. This new range of body types raises concerns about designing equipment and acquiring systems for servicemen and women of increasingly varying sizes. During the acquisition of new trainer aircraft in the early 1990s, the limitations of existing datasets and the need for civilian population data became especially evident.

The European Community (EC) also needs a civilian database, particularly after the enactment of an EC law requiring that products marketed in the EC must "fit" users from all EC countries. The inter-operability of military equipment throughout NATO countries is an important concern for both the American and the European defense communities.

With these concerns in mind, the NATO Advisory Group for Aerospace Research and Development (AGARD) recommended that NATO member nations cooperate to create a civilian database available to government agencies, researchers, and manufacturers around the world. Starting in September, 1997, the CARD Lab, The Netherlands Organization for Applied Scientific Research (TNO), and numerous universities and corporations will launch CAESAR, a multi-national project to scan and measure civilians in the U.S., the Netherlands, and Italy.

CAESAR will create a database of 13,000 civilian subjects, representing the variability of men and women in Europe and North America. The survey is to start in the United States, the NATO member nation with the largest population, followed by the Netherlands, whose population contains some of the tallest people in NATO, and Italy, whose population contains some of the shortest people in NATO. CAESAR's data collection methods will be standardized so that the database can be consistently expanded and updated.

Initial work for the survey is well underway. Kathleen Robinette, CARD Lab Director, and Hein Daanen of TNO, the project's European coordinator, have completed a business and management plan, and are finalizing agreements with candidate partners. Hein Daanen is also completing a six-month research project in the CARD Lab, investigating body positioning and scanning accuracy issues with the WB-4 scanner. The CARD Lab's software development team has developed and released a preliminary version of the data handling software, will release a more refined version of the software in 1997, and will soon offer a training course for users. ●

Private organizations interested in CAESAR should contact:

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Email: gary@sae.org

Interested government organizations should contact:

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CARD Lab
2255 H Street, Room 3003
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45433-7022

Tel: 937-255-8810
Email:
krobinette@falcon.al.wpafb.af.mil

To find out more about other CARD Lab projects, past, present, and future, visit the CARD Web site: http://www.al.wpafb.af.mil/~cardlab.

Matt Brunsman is a Biomedical and Human Factors Engineer with Sytronics, Inc., Dayton, OH. Hein Daanen is a Workplace Ergonomics Program Manager with TNO Human Factors Research Institute, Soesterberg, The Netherlands. Patrick Files is a Technical Writer and Anthropometric Technician, also with Sytronics, Inc.

References

Burnsides, D. B., Files, P., & Whitestone, J. J. (1996). *Integrate 1.25: A Prototype for Evaluating Three-dimensional Visualization, Analysis and Manipulation Functionality* (AL/CF-TR-1996-0095). WPAFB, OH: Armstrong Laboratory, Crew Systems Directorate, Human Engineering Division.

Kline, Y., & Whitestone, J. J. (1995). *An Investigation of the Usefulness of 3-D Digitized Facial Images for the Issuance of the MCU-2/P Protective Mask* (AL/CF-TR-1995-0162). WPAFB, OH: Armstrong Laboratory, Crew Systems Directorate, Human Engineering Division.

Robinette, K. M., & Whitestone, J. J. (1992). *Methods for Characterizing the Human Head for the Design of Helmets* (AL-TR-1992-0061). WPAFB, OH: Armstrong Laboratory, Crew Systems Directorate, Human Engineering Division.

Whitestone, J. J. (1993). Design and Evaluation of Helmet Systems Using 3-D Data. *Proceedings of the 37th Annual Meeting of the Human Factors and Ergonomics Society, 1,* 63-66.

Whitestone, J. J. (1994). Improving Total Contact Burn Masks: Three-Dimensional Anthropometric Imaging Techniques. *CSERIAC Gateway, V*(3).

The CSERIAC Anthropometric Data Files

Rebecca A. Unger

In 1994 the Crew System Ergonomics Information Analysis Center (CSERIAC) acquired a large repository of data from the Computerized Anthropometric Research and Design (CARD) Laboratory of the Paul M. Fitts Human Engineering Division of the Armstrong Laboratory. This repository of data, originally called the Aerospace Medical Research Laboratory (AMRL) Anthropometric Data Bank, consists of over fifty US and international anthropometric surveys on both military and civilian populations. These traditional, or two-dimensional surveys, represent more than forty-five years of research and account for hundreds of measurements on thousands of individuals. Throughout the years, these data have been critical in the design of clothing, personal protective equipment (PPE), work-spaces, equipment, and vehicles. Though some of these surveys were conducted decades ago, the data remain a valuable resource for design purposes.

Although more efficient and sophisticated anthropometric data collection methods are emerging, the value and applicability of the existing traditional survey data should not be discounted. For instance, two-dimensional anthropometry remains the primary source of data for creating three-dimensional man models for use in Computer-Aided Design (CAD) software programs. The joint locations used to create the dimensions of the model are based on typical anthropometric measures and depend on the landmark locations of these measures for verification and validation of the population that is represented.

In addition, these data are also essential for forecasting future trends in populations. Anthropometric forecasting involves analyzing the historical trends of a few dimensions, namely stature and weight, and using this information to predict future trends in a particular population. This process is useful for the design of systems that will take years to develop or for systems that will be used for many years to come.

Survey Standardization

CSERIAC approached the task of maintaining this large repository of data with the idea of simplifying the overwhelming nature of such an abundance of information. The first step was to obtain documentation on as many data files as possible so the details of each survey could be evaluated and compared to the other surveys. Since these surveys were conducted by many individuals and organizations over a long period of time, the measuring techniques and the terminology were not always consistent from survey to survey. For example, "stomach depth" in one survey may have been termed "abdominal depth" in another survey (terminology inconsistency) and waist circumference may have been measured at the level of the navel in one survey and the level of the subject's waist natural indentation in the next survey (measuring technique difference).

To eliminate these inconsistencies and the confusion they create, CSERIAC performed an exhaustive evaluation of all the surveys for which the documentation could be obtained, determined the similarities and differences between the surveys and the measurements, and developed a standardized coding scheme to be applied to the dimensions across all of the surveys.

A total of 37 surveys have been evaluated and are now available for general use. Each survey contains the original ASCII dataset file and a text file that describes the survey, provides the documentation reference, and lists the specific variables that are included in the survey. The ASCII data can be directly imported into any statistical software package on a personal computer (PC) or Macintosh™ computer for analysis. In addition, a reference catalog is included that provides the user with a complete list of the standardized measurements, a glossary of anthropometric landmarks, and a glossary of measurement descriptions.

A categorical breakdown of the surveys that are available through CSERIAC is given in Table 1.

Depending on the analysts' or designers' needs, any number of these surveys can be ordered for a cost-recovery fee from the CSERIAC Program Office. Inquiries for obtaining these surveys may be directed to Chris Sharbaugh, CSERIAC Product Manager. ●

Rebecca A. Unger is a Human Factors Analyst with the CSERIAC Program Office.

Table 1. Breakdown of available surveys.

	International	United States
Military	12	21
Civilian	0	4
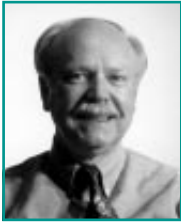
The COTR Speaks

Reuben "Lew" Hann

The measurement of the human body, anthropometry, has always been a major area of interest for the ergonomics community in general, and clothing and equipment designers in particular. The way in which these measurements are taken is changing rapidly and the Computerized Anthropometric Research and Design (CARD) Laboratory of the Armstrong Laboratory's Human Engineering Division is at the forefront of these changes. Computer imaging technology, which provides 3-D data, is augmenting and may eventually replace the use of calipers and tape measures, which provide 2-D data. A group of scientists within the CARD Lab have provided us with an article documenting the great changes that are happening in the area of body scanning technology.

While many changes are forthcoming in the world of anthropometry, 2-D data are still extremely useful. And a large collection of 2-D data has been transferred to CSERIAC from the CARD Lab for distribution. Becky Unger, a CSERIAC Human Factors Analyst, gives us an overview of this collection of data.

In the "CSERIAC Interface," CSERIAC Chief Scientist Ron Schopper concludes the discussion began in the last issue of *Gateway* about the May 1996 Biennial Meeting of the US Department of Defense Human Factors Engineering Technical Advisory Group. If you recall, the last installment covered the tours given by the host facility, NASA Johnson Space Center, Houston, Texas. This installment provides an overview of the actual meeting.

The Armstrong Laboratory Colloquium speaker featured in this issue is Dr. Grete Myhre, a Psychologist with the Royal Norweigan Air Force Institute of Aviation Medicine. She spoke during the 50th Anniversary week of the Human Engineering Division last year. Her lecture topic focused on the role of human factors in the Royal Norwegian Air Force. She was kind enough to give us a written synopsis of her lecture for publication in *Gateway*. During her visit I had the chance to speak with her; an edited transcript of this interview follows the synopsis.

The featured human factors laboratory for this issue is the US Army Aeromedical Research Laboratory at Ft. Rucker, Alabama. Dr. Kent Kimball

reviews the mission and organization of this important laboratory as well as its research program, which studies areas like visual performance, crew-rest strategies, damage-risk criteria for hearing, and the effects of repetitive impact. These issues are relevant to all human factors practitioners.

Also in this issue is an article written by Dr. Mary Stearns of the FAA's Volpe National Transportation Center, Cambridge, Massachusetts. Mary provides us with information about a new FAA product, the *Human Factors Checklist for the Design and Evaluation of Air Traffic Control Systems* (available in electronic and hard copy) and its reference text, *Human Factors in the Design and Evaluation of Air Traffic Control*

Systems. These were developed by the FAA to allow for more effective evaluation of air traffic control equipment.

Closing this issue is a brief article by David Johnson, Johnson Kinetic Systems Corporation, on a new technology that enables the tracking of body position in a variety of situations. He has developed the PhysioKinetics (PK) goniometer platform of wearable tracking devices which can measure over 88 different human joints across various environments.

Finally, it is with mixed feelings that I must tell you this is my last column of "COTR Speaks." After 26 years of government service–the last four as the CSERIAC Contracting Officer's Technical Representative–I will be retiring in January 1997. It has been a

great experience serving as the government technical monitor for this fine organization. In one capacity or another I have been involved with CSERIAC from the very beginning, and it has been a pleasure watching it grow from the initial crew of 6 to its present staff of more than 30 persons. My successor is AF Captain Joseph Balas. Under Joe's guidance, I am confident CSERIAC will continue to flourish and provide first-class ergonomics information analysis services for the DoD, industrial, and academic communities. ●

Reuben "Lew" Hann, Ph.D., is the Contracting Officer's Technical Representative (COTR) who serves as the Government Manager for the CSERIAC Program.

Calendar

February 24-27, 1997
San Diego, CA, USA
Occupational Ergonomics: Work Evaluation and Prevention of Upper Limb and Back Disorders Course. Jointly sponsored by the University of Michigan; American Industrial Hygiene Association, San Diego Local Section; and State Compensation Insurance Fund of California. Contact Conlin/Faber Travel, PO Box 1207, Ann Arbor, MI 48106-1207. Tel: 1-800-426-6546, Fax: 313-677-0901.

February 28-March 1, 1997
San Diego, CA, USA
Ergonomic Job Analysis Course. Jointly sponsored by the University of Michigan; American Industrial Hygiene Association, San Diego Local Section; and State Compensation Insurance Fund of California. Contact Conlin/Faber Travel, PO Box 1207, Ann Arbor, MI 48106-1207. Tel: 1-800-426-6546, Fax: 313-677-0901.

April 15-17, 1997
Grantham, United Kingdom
The Ergonomics Society Annual Conference 1997. Contact Conference Manager, The Ergonomics Society, Devonshire House, Devonshire Square, Loughborough, Leicestershire LE11 3DW, United Kingdom. Tel & Fax: +44-509-234904, WWW: http//www-hcs.derby.ac.uk/ergonomics/

May 4-7, 1997
Palo Alto, CA, USA
ErgoCon '97. 3rd Annual Silicon Valley Ergonomics Conference & Exposition. Contact Abbas Moallem, Ph.D., ErgoCon '97 Conference Chair, Silicon Valley Ergonomics Institute, San Jose State University, One Washington Square, San Jose, CA 95192-0180. Tel: 408-924-4132, FAX: 408-924-4153, Email: amoallem@isc.sjsu.edu

May 11-16, 1997
Boston, MA, USA
SID '97. Society for Information Display International Symposium, Seminar, and Exhibition. Contact Hugo Steemers, SID '97 Symposium Chair, dpiX, A Xerox Company, 3406 Hillview Avenue, Palo Alto, CA 94304-1345. Tel: 415-812-4513, Fax: 415-812-4502, Email: steemers@parc.xerox.com

June 1-4, 1997
Washington, DC, USA
12th Annual International Occupational Ergonomics and Safety Conference. Contact Biman Das, Technical University of Nova Scotia B3J 2X4, Canada. Tel: 902-420-7606, Fax: 902-420-7858, Email: dasb@tuns.ca

June 8-12, 1997
Orlando, FL, USA
IEEE 6th Conference on Human Factors and Power Plants. Contact Stephen A. Fleger, SAIC, 11251 Roger Bacon Drive, Reston, VA 20190. Fax: 703-709-1039, Email: stephen.a.fleger@cpmx.saic.com

June 29-July 4, 1997
Tampere, Finland
13th Triennial Congress of the International Ergonomics Association, "From Experience to Innovation." Contact Prof. Markku Mattila, Tampere University of Technology, Occupational Safety Engineering, PO Box 589, FIN-33101 Tampere, Finland. Tel: +358-31-3162-621, Fax +358-31-3162-671, Email: mattila@cc.tut.fi

August 24-29, 1997
San Francisco, CA, USA
HCI International '97. 7th International Conference on Human-Computer Interaction jointly with 13th Symposium on Human Interface (Japan). Contact Dr. Gavriel Salvendy, General Chair, or Kim Gilbert, Conference Administrator, School of Industrial Engineering, Purdue University, 1287 Grissom Hall, West Lafayette, IN 47907-1287. Tel: 317-494-5426, Fax: 317-494-0874, Email: salvendy@ecn.purdue.edu, WWW: http://palette.ecn.purdue.edu/~salvendy/hci97/

Notices for the calendar should be sent at least four months in advance to:
CSERIAC Gateway Calendar, AL/CFH/CSERIAC Bldg 248, 2255 H Street, Wright-Patterson AFB OH 45433-7022

The CSERIAC Interface

Aaron "Ron" Schopper

Editor's note: The following is the second part of a two-part article detailing the May 6-9, 1996 Biennial Meeting of the Deparment of Defense Human Factors Engineering Technical Advisory Group. The first part appeared in the last issue of Gateway (Vol. VII, No.1).

What do speech-monitoring technologies; risk analysis models; advanced command control, communication, and intelligence displays; reviews of the effectiveness of computer-based training programs; and adaptive aiding technologies for vehicles have in common? Well, you can think on it for a while, but my quick answer is that they were all topics addressed at a recent DoD Human Factors Engineering Technical Advisory Group (DoDHFETAG) meeting. And while they do represent issues and concerns of direct interest to the DoD, there are counterparts within the non-DoD community wherein the findings evidenced and technologies developed have application.

Speech Patterns and Operator Fatigue

An obvious example is the research by Jeffrey Whitmore and William Storm of the USAF Armstrong Laboratory's Sustained Operations Branch, Brooks Air Force Base, Texas. The need for valid, reliable, non-obtrusive means of monitoring and assessing an operator's state is an important one in areas wherein operators must sustain high levels of perceptual vigilance and cognitive function for extended periods. Be those applications within military scenarios using military hardware (as in Whitmore and Storm's research), or within the context of nuclear power plants, industrial process control rooms, or air traffic control towers, the information developed has relevance.

Given the unobtrusive nature of speech monitoring, Whitmore and Storm explored the use of speech characteristics as an indicator of operator state during extended wakefulness. They investigated 12 male aircrewmen who participated in teams of four during three 36-hour simulated missions in a USAF B1B bomber simulator. Each 36-hour mission was interspersed with a 36-hour rest period. Measures of speech, cognitive function, and subjective fatigue were collected every 3 hours during each 36-hour mission.

Their speech analyses, confined to the word "Magellan," revealed significant variation in both the fundamental speech frequency (range: 107-117 Hz) and in utterance duration (range: 0.41-0.47 s) over the periods measured. The highest frequency was observed at 2200 hours and 1300 hours and the low occurred at 0100 of the initial day and again at 0700 the next morning. An examination of the means showed both the increase between 0100 and 1300 and the subsequent decrease until 0700 the following morning were reasonably linear. The overall trend of the utterance durations was a shortening over the 36-hour period. Relative peaks in duration occurred at 0300 the first morning (0.47 s) and at 0100 the second morning (0.45 s). There was relatively little variation (0.42-0.43 s) from 0700 of the first morning to 2100 the next evening.

The relationship between cognitive task performance (response time to a logical reasoning task) and the change in subjective fatigue was reasonably strong. Response time was slowest and subjective fatigue was high between 0300 and 0800 of the first 24 hours; the reverse was true between 1200 and 1300. There was little relationship between accuracy of cognitive performance and speed of performance during the initial half of the 36-hour period; however, the data plot suggested the existence of a speed-accuracy tradeoff during the final 16 hours as accuracy increased and response time slowed. Whitmore and Storm concluded that variation in speech patterns may provide a viable, non-obtrusive means of assessing operator fatigue. (Mr. Whitmore can be contacted at 210-536-3464 or jnw@aesop.brooks.af.mil.)

Risk Exposure

Dr. Mark Brauer, currently an Associate Professor at Texas A & M University, Kingsville, is a long-time member of the TAG. He presented a context-independent risk-analysis "safety cube" model that he is developing. He noted that current textbooks and US Government Standards dealing with the topic use mishap severity and likelihood as the only factors considered, ignoring the impact of exposure. As an example of the nature of the issue, he used the analogy of a bus approaching a pothole. The depth of the pothole represents the anticipated severity of a possible mishap, and the width of the pothole corresponds to the likelihood that a mishap will occur. Previous assessments would stop at this level of analysis. However, Dr. Brauer indicated that the anticipated exposure level should also be

considered, in this case represented by the number of occupants on the bus. By incorporating exposure into the model, he believes that decision makers will be better informed when design-related decisions are to be made. Dr. Brauer also described how this 3-dimensional model could provide a single-valued metric that would facilitate comparison (e.g., in a trade-off matrix) to assess the risk associated with various candidate designs (alternatives) being considered. He indicated that he was in the process of refining his model and was seeking feedback and comments. (In our subsequent discussion with him, he indicated that he would be willing to provide any interested reader with a more detailed description of his model if the reader would agree to provide him with the feedback he is soliciting. Dr. Brauer can be reached at [Tel] 512-593-2320, [FAX] 512-593-2371, or m-brauer@taiu.edu.)

Adaptive Interfaces for Ground Vehicle Navigation

In another area, the human factors issues being addressed by Christopher Smyth in his studies on adaptive filter design for display interfaces evidence some overlap with those associated with the development of the nation's Intelligent Vehicle Highway System (IVHS) program. Chris is on the staff of the Human Research & Engineering Directorate, US Army Research Laboratory (ARL) at Aberdeen Proving Grounds, Maryland. He described a project entitled Adaptive Aiding in (Simulated) Ground Vehicle Waypoint Navigation which is being developed for driving by indirect vision and teleoperations. The application entails the use of an integrated display that depicts a task event history, a task event predictor, and a situation awareness component. The display also includes a primary task area to support the immediate execution of the driving task with cueing information pertinent to near-future actions. Related areas provide alerts,

advisories, and action-confirmation notices. A separate display area allows the driver to manipulate the display format to best accommodate his tasks.

During operation, impending tasks are stored in a context-sensitive manner and are compared to the output of an activity monitor which maintains a real-time record of the driver's current control inputs and psychomotor activity. The output of this adaptive aiding comparator (labeled a *Tolman Filter*, acknowledging the work on cognitive maps by an early prominent psychologist, Edward Tolman) is fed to a "cueing queue" which sends appropriate cues to the display used by the vehicle driver. The *Tolman Filter* compares the patterns of present activities to those of previously prepared task scripts to effect the best match. A real-time *Task Parser* produces the task scripts from information relating to the current terrain and task needs. In turn, an *Activity Classifier* module classifies the current activities of the driver/operator as completed tasks. The current operational state of the driver is then used in conjunction with the task-related activities emanating from the driver/operator model to produce the task-related cues needed to facilitate the performance of time-critical inputs associated with the current task.

As conceived for implementation in tactical vehicles, additional advanced technologies would be used to assess the current status of the operator (e.g., physiological monitors of EEG, EMG, and EKG activity; speech monitoring modules; eye and head movement tracking devices; and control activation monitors), and it would use equally advanced technologies to provide navigational cues and additional task-related information (e.g., 3-D sound localizing inputs, speech generation systems, and real-time digital map displays).

During initial feasibility testing, the concept proved to be potentially useful. Chris reported that the alert cueing provided during a simulated driving task to inform the operator that

he or she was "out-of-bounds" was perceived to be "natural"–as were those used to provide confirmation of corrective actions. However, the operators also indicated that on those occasions when the visual and acoustic cues were somewhat "out-of-sync," the perceived workload was increased. Additionally, Chris observed that, to their detriment, operators occasionally allowed themselves to become more involved in responding to the cues and prompts than to the primary driving scene appearing on the display. (Mr. Smyth can be contacted at 410-278-5942 or csmyth@arl.mil.)

Large-Scale Situation Display

Mr. Michael Barnes of ARL's Field Element at Fort Huachuca, Arizona, described a large-scale Command, Control, Communication, and Intelligence (C3I) collaborative effort among principals from multiple military organizations, universities, and contractors. The objective is to develop predictive, process-centered displays that are dynamically updated and prioritized in a context-sensitive manner. Again, there is potential applicability to many process-control and dynamic monitoring applications. In the application of interest, the focus is on a large-scale situation display that has been provided with screen insets to assist the viewer in his or her efforts to maintain (a) a broad appreciation of the overall context, (b) a detailed visualization of a small portion of the area viewed, and (c) a current appreciation of the status of progress and resources available. This is achieved via the use of a large-scale map display with two insets. One inset provides information regarding the current status of the process (e.g., military engagement). A dynamically changing rectangle uses variation in the vertical dimension to represent the predicted amount of time remaining until the task is completed (e.g., until the objective has been reached). The horizontal dimension represents a

composite metric that indicates the current effectiveness of the operation. Changes in the shape of the rectangle provide immediate information regarding the overall status of the operation. This inset also includes a set of vertical bar graphs that portray both analog and digital values of additional, important individual operational parameters. The other, second inset provides an expanded image of a user-selected portion of the overall map display. Research undertaken to date on the status display inset has shown the configural display to be superior to both a previously existing "standard" display and one that provided information solely via alphanumeric characters. Future research pertaining to the overall map display will evaluate issues relating to the differential effectiveness of 2-D and 3-D display representations, and will assess the impact of degraded display conditions, the use of predictive displays, and the use of various information prioritization schemes. (Mr. Barnes can be reached at 520-538-4704.)

Computer-Based Instruction

Dr. Dexter Fletcher of the Institute for Defense Analyses (IDA), Alexandria, Virginia, provided an informative presentation on the use of computer-based training within and without the DoD. He first noted that the DoD's training program is extensive (more than 20,000 courses) with a heavy investment in individual training. He noted, too, that the DoD is a major, national contributor to research and development in the area of instructional technology, pursuing research in the areas of computer-based instruction (CBI), instructional simulators and simulation, adaptive testing, distance learning, collective training (crew, group, and unit training), "intelligent" training systems, interactive multimedia instruction, and virtual reality.

Dr. Fletcher presented a summary of both recent IDA reviews and earlier reviews wherein it was possible to estimate the extent to which the use of some form of instructional technology affected performance relative to a control group. Among military populations, the average impact of 38 studies of CBI was the equivalent of elevating mean performance from the 50th percentile to the 66th percentile. Based on comparisons with literature reviews published in the mid-eighties, these DoD program results were generally comparable to or better than those encountered among the civilian population for adult classes (24 studies, 66th percentile) and for higher education classes (101 studies, 60th percentile). Comparisons among populations using Interactive Video-disc Instruction (IVI) showed the mean effect for military training (24 studies) to be an elevation to the 65th percentile. The use of this technology in industrial training settings has yielded a mean increment of nearly 20 percentile points (70th percentile, 9 studies), and in higher education programs, a mean advantage of 25 points (75th percentile, 14 studies) was reported. Across populations, the results of reviews of outcome studies addressing knowledge (27 studies) and performance in a more applied sense (20 studies) have shown a mean increase to the 65th percentile for both types of outcome measures.

In addition to assessing the performance-related impact of instructional technologies, Dr. Fletcher also presented information on two other key training-related parameters: time-to-train and cost. Predicated on the results of three recent studies and four literature reviews, he indicated that the typical instructional time savings reported for CBI programs was approximately 30%–a value that appeared to be stable over the time-frame considered (1970s through the present). Available information pertaining to cost indicated that the mean initial investment costs associated with CBI were 43% of those for comparable conventional instruction and that operating and support costs were but 1/6th those of comparable conventional instruction programs. Many of these cost reductions were due to the substitution of computer-based, tutorial simulations for laboratory experience with actual equipment. (Data pertaining to two other costs, research and development [R&D] costs and salvage costs, were not available.) The review of available cost effectiveness studies indicated that marked variation existed within the literature, albeit he reported some indications that combining CBI with some form of peer tutoring may represent the most cost-effective approach. In concluding, Dr. Fletcher indicated that the increasing uses of CBI programs may have their most significant impact on force readiness by supplying more people, sooner, to their duty assignments and, once there, providing them readily accessible means to sustain and improve their competence. (Dr. Fletcher can be reached at 703-578-2837 or fletcher@ida.org.)

Conclusion

The diversity of DoDHFETAG presentations made during such meetings–and the issues they address–is comparable to that evidenced in other large human factors meetings. While the focus is on DoD applications, those responsible for the agenda are experienced human factors professionals with considerable knowledge of emerging trends outside the DoD and the capability to bring them to the DoD. Consistent with its charter, cross-service and DoD/non-DoD pollination and inspiration occur during the DoDHFETAG meetings–something that ultimately benefits us all. ●

Aaron "Ron" Schopper, Ph.D., is the Chief Scientist for the CSERIAC Program Office.

GATEWAY

CSERIAC Techology Teams

CSERIAC has organized and implemented Technology Teams chartered with developing and maintaining a corporate knowledge base of their respective technologies. This exciting new concept will provide a single authoritative DoD point of contact for human factors information and assistance in these specific, high-interest areas. Five Technology Teams were established to address current science and technology (S&T) challenges. To keep pace with the dynamic S&T environment new teams will be added as necessary. If you have information in one of these areas you wish to share, please contact the Technology Team Managers listed below:

CSERIAC Technology Managers

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Dear CSERIAC...

To show the diversity of support that CSERIAC provides, this column contains a sampling of some of the more interesting questions asked of CSERIAC. In response to these questions, CSERIAC conducts literature and reference searches, and, in some cases, consults with subject area experts. These questions have been compiled by David F. Wourms, Technical Inquiry Group Manager. If you would like to comment on any of these questions or issues related to them, please write to "Dear CSERIAC" at the address found on the back cover of *Gateway* or email Dave Wourms at wourms@cpo.al.wpafb.af.mil.

■ The principal scientist from a private consulting firm in Louisiana contacted CSERIAC to obtain information on ergonomic and safety issues related to excessive overtime in industrial plants.

■ A design engineer from a prominent manufacturer of baby products requested information on adult pinch and grip strength.

■ An Air Force researcher requested references on the topic of head, neck, and helmet dynamics during pilot ejection.

■ An occupational therapist from a private consulting firm requested bibliographic citations and point-of-contact information on work being performed in the area of rest and the prevention of cumulative trauma disorders (CTDs).

■ The safety supervisor from a Midwest manufacturing plant requested information on the use of job aids (e.g., checklists) to prevent errors of omission during loading and shipping operations.

■ An engineer from a major airframe manufacturer requested information on landing displays appropriate for vertical take-off and landing aircraft.

■ The director of engineering from a Southwest manufacturing firm contacted CSERIAC for information regarding the use of push-button safety restraints in the aerospace environment.

■ An engineer from a video display terminal (VDT) equipment manufacturer requested guidelines and studies related to reducing the effects of low-frequency radiation from VDTs.

Armstrong Laboratory Human Engineering Division Colloquium Series
Human Factors in the Royal Norwegian Air Force

Grete Myhre

Norway has a small national defense force, consisting of an Army, a Navy, and an Air Force. The Royal Norwegian Air Force (RNoAF) manages about 80 fighter planes, 12 transport planes, 34 helicopters, including coast guard and search-and-rescue units. In addition we have 17 trainers. It is a small force, but the beauty of being small is that it is easy to follow-up on and look after flying personnel. The Institute of Aviation Medicine (IAM) is organized directly under the Inspector General of the RNoAF. The institute consists of five full-time medical doctors, specialists in aviation medicine; one full-time scientist, one psychologist; three laboratory technicians; one second lieutenant specializing in personal pilot equipment; one conscript; and 2 secretaries. Twenty years ago "human factors" was an almost unknown term in the RNoAF. In 1976, the Institute was reorganized and got a new dynamic director, Professor Harald T. Andersen, M.D. and Ph.D., who created a human factors branch, and research department and teaching departments. Current human factors activities include a research program, human factors courses, fighter pilot instruction, accident investigation, and psychological debriefing after accidents and incidents.

Research projects include a 1978 joint IAM/RNoAF British Royal Air Force study of the extent to which different day lengths affected sleep patterns of shift workers within the Arctic Circle. Some years after this study, scientists from NASA's Moffett Field invited the IMA/RNoAF to participate in a world-wide study on the effects of time zone changes on fatigue and the circadian rhythms of sleep and wake in pilots.

Courses taught by the IAM focus on many human factors topics. In Norway, different NATO-required courses are arranged for fighter pilots, helicopter crews, and transportation pilots emphasizing their various working conditions. Fighter pilots, for instance, are taught about G-lock and hypoxia, helicopter crews get information on vibration and noise, and transportation pilots are informed about sleep and sleep problems. One of the newest IAM courses is about CRM. Today CRM means company resource management training, including squadron leaders and base commanders.

Fighter pilot instruction has been a special focus of the IAM since 1989, a bad year for accidents for the RNoAF. Many of the accident reports revealed that the instructors' attitudes toward jobs and in relation to the student pilots were negative. A program was enacted in which fighter instructors received basic training in education , and it was stressed that only pilots interested in instruction should be allowed to participate in pilot training. Instructors were trained in how to integrate aspects of personality and coping abilities into their teaching.

Accident investigation in the RNoAF now uses more useful and specific categories than the historical "pilot

Figure 1. Grete Myhre, Royal Norweigan Air Force.

error," which does not adequately identify areas needing improvement. In changing the categories and splitting them into different human factors areas, it is easier to get the flying community's attention when teaching accident prevention.

Psychological debriefings after accidents/incidents are based on new knowledge about post traumatic reactions related to accidents. Many-traumatic emotional reactions are not identified right after the accident. Most signs and symptoms of emotional disturbance in aviators are not easily detected, but may appear subtly as safety, satisfaction, and retention problems. On the other hand the emotional failure process is insidious and may in its final consequence lead to sudden incapacitation. ●

Armstrong Laboratory Human Engineering Division Colloquium Series
A Conversation with Grete Myhre

Reuben "Lew" Hann

Editor's note: Following is an edited transcript of a conversation with Dr. Grete Myhre, Institute of Aviation Medicine, Royal Norwegian Air Force. She spoke on "Human Factors in the Royal Norwegian Air Force" as a guest speaker for the 1995 Celebration of the 50th Anniversary of the Paul M. Fitts Human Engineering Division. The interviewer was Dr. Lew Hann, CSERIAC COTR. JAL

CSERIAC: First of all, a bit about your background. I see your degree is in experimental psychology. Tell me, in Norway is there such a thing as a human factors or ergonomics "major," as we call it here in America?

Dr. Myhre: No, but as a matter of fact, the University of Oslo is working on such a program. I teach there and started out by offering a course in the psychology of the cockpit. The first time it was offered it was just an experiment; I wanted to see how it would be accepted. It developed so much interest that it has now become a permanent part of the masters of psychology degree program. They are considering creating a professorship in the area of the psychology of the cockpit.

CSERIAC: It must be very exciting to be involved in the establishment of a new program such as this.

Dr. Myhre: Oh yes. It turns out that clinical psychologists-to-be, as well as experimental and cognitive psychologists-to-be are interested in this area.

CSERIAC: For as long as I can remember, the expression "human factors" or "human engineering" was used very little in Europe. Everything in this area was classified as "ergonomics." Has that changed any in recent years?

Dr. Myhre: Actually, in Norway we never felt that "ergonomics" was the right word to describe our work, so the fact is we have been using "human factors" for at least the past 15 years.

CSERIAC: How were you able to gain the trust of operational pilots, so that they would volunteer to participate in your cockpit resource management research?

Dr. Myhre: It started out in 1978 with my going out to the various bases; I went to the squadron rooms and talked to the pilots. In the beginning they were frightened, because they heard I was a psychologist. They just sat across the room and refused to talk with me. But in such groups there are always one or two individuals who are not so threatened and are willing to talk. Gradually, they found out I was not a threat, and became much more willing to discuss their problems.

It is interesting to note that at this time I was not even working for the Air Force; I was there only on a consulting basis. It turned out that the pilots phoned the Institute for Aviation Medicine and asked that I be involved. Since I was not even a government employee, the General Inspector had to create a new position for a psychologist. I even had the opportunity to write my own job description.

CSERIAC: I understand that you spent some time in the US at Brooks Air Force Base.

Dr. Myhre: Yes. In 1985 a US Air Force colonel visited our lab and said that I should take the course at Brooks normally intended for medical doctors; he said they were trying to establish a program for psychologists there. I was lucky I was invited. I believe I am the only foreigner to have taken that course. I believe there are a total of 15 persons who have taken it. The course was later dropped because of costs; I was very fortunate that I had the chance to study there.

CSERIAC: I see you have done a lot of investigation in the area of work/rest cycles.

Dr. Myhre: Yes. In fact, that is how I became involved originally with the Institute. The Director had been approached by the British Royal Air Force (RAF) and NASA for assistance in this area, and the only person he knew at the time who might help in the project was me. This is when I started interacting with the pilots on a regular basis.

CSERIAC: One of your findings was somewhat of a surprise, namely that persons who live in the high northern latitudes do not show any different sleep patterns from persons in areas where the day/night variations throughout the year are less extreme.

Dr. Myhre: Yes. The only thing we found was just a bit more restless sleep during fall and winter. Actually it was not even statistically significant. The RAF had done an experiment in the Mediterranean area and wanted to compare that with results from our region. They expected a large difference in the sleep cycle patterns, but of course that turned out not to be the case. We found that people could cope very easily with the unusual sleep conditions required for shift work during the winter in Norway. We also found that these people were all what we call type "B" sleepers; that is, they prefer to go to bed late and sleep late in the morning. They seem to be more flexible than the "A" types-those who are early to bed and early to rise. By the way, 85 to 90 percent of our pilots report that they are "B" types. The "A"

types were practically all fighter pilots, who don't have the requirement for many night operations.

CSERIAC: How big is the Norwegian Air Force presently?

Dr. Myhre: We have 80 fighter planes, 12 transport planes, 34 helicopters, and 17 trainers. There are roughly 250 pilots. Additionally, there are 500 "flight personnel," as we call them. Because the service is so small, I know almost all the pilots by name. This is an advantage when interacting with them, of course. It is much easier to get their trust when collecting data.

CSERIAC: Do you have any female pilots?

Dr. Myhre: Absolutely! Furthermore, they operate on the same basis as the male pilots. So, if we went to war, they would serve in combat. I was on a committee studying whether this is appropriate. The Director of the Institute and I came to the U.S., where we visited several bases to see how it was working out here. As far as I could see, they were functioning very well; I could see no reason for them not to serve in combat as well. So we advised the Norwegian government that female combat pilots should be accepted and be made fully equal to the male pilots.

We have only two female fighter pilots so far, but they have an excellent performance record. That, of course, has been very helpful in gaining acceptance by the rest of the pilots.

CSERIAC: Does Norway have an equivalent of our Air Force Academy?

Dr. Myhre: Yes, it is located in Trondheim, in the center of Norway. It is separate from the Army Academy of War and the Navy Academy of War. The training is on two levels. On the first level they finish some basic required academic work, go to flight school, and then they go to the States for a year of special training. The don't have to proceed to the second level after that, although we find more and more pilots do this now. On the second level they must major in one of the topics offered at the Academy. What is interesting is that more and more of the pilots are majoring in psychology. Prior to this, they majored in history and similar areas. Of course, there are not that many positions which require a psychology background. However, they have found this kind of education to be very useful in becoming better managers or squadron leaders. It has the added advantage of creating a generation of pilots who are sensitive to the importance of the human in the system and how system design must allow for human abilities and limitations. ●

US Army
Aeromedical Research Laboratory

Kent A. Kimball

The United States Army Aeromedical Research Laboratory (USAARL) is located at Fort Rucker, Alabama, the "Home of Army Aviation." One of six laboratories within the US Army Medical Research and Materiel Command, USAARL was established in 1962 to provide direct aviation medical research support to all Army aviation and airborne activities.

This mission has expanded over the 34 years since USAARL's activation, to include being designated as lead medical laboratory for vision and acoustics research in 1974. An additional mission to conduct health hazard assessments and countermeasures research on air and tactical ground vehicles and weapons systems was added in 1977. Nevertheless, its primary mission remains medical research support of Army aviation.

Stated simply, USAARL's mission is to enhance our force's effectiveness by preventing or reducing health hazards created by military systems, doctrine, or tactics.

Our research includes the following major tasks:

■ Conduct research and development on health hazards of Army aviation, tactical combat vehicles, and weapons systems.

■ Assess health hazards of noise, acceleration, impact, visual demands, and stress and fatigue of systems operators.

■ Assess life support equipment for failure and recommend improved design.

■ Assist in the development of aircrew entry and selection and retention criteria.

Organization and Staffing

We have configured our Laboratory into two research divisions, the Aircrew Health and Performance Division and the Aircrew Protection Division, and one research support division. Our on-site staff consists of 25 scientists and engineers, 43 technical support, and 31 administrative personnel. USAARL also sponsors contract research projects, both on-site and at academic and other government-owned/contractor-operated facilities.

Research Programs

USAARL research programs are applied in focus and multidisciplinary in execution.

The Aircrew Health and Performance Division accomplishes research within two primary areas–visual performance and aircrew performance and sustainment. In visual performance, our research provides information about the capabilities, limitations, and characteristics of the human visual system and assesses the impact of military equipment, environments, and operations on visual performance. This research team assesses military viewing and display systems to determine the optimum display characteristics for compatibility with the human visual system, and develops tests for visual function to be applied to selection and retention standards for aircrews. Projects within this area include in-flight performance impact of helmet-mounted visual displays causing visual distortions (see Fig. 1); visual and physical performance requirements for flat-panel visual displays; and new color and low-contrast spatial resolution vision tests for screening aviator candidates and improving early detection of visual dysfunction.

In aircrew performance and sustainment, scientists conduct applied laboratory and field research to determine the impact of and recommend coun-

Figure 1. ARL helmet-mounted display.

Figure 2. Cockpit airbag system.

termeasures for the hazards created by military systems, technology, and doctrine. Projects include crew rest strategies for helicopter pilots and crews in night operations; efficacy of melatonin for readjusting circadian rhythms in deployed Special Operations forces; and efficacy of sleep- and alertness-enhancing countermeasures in sustaining performance during continuous operations.

The Aircrew Protection Division researches three primary areas: communications/noise protection, impact biomechanics/crashworthiness, and repetitive impact.

Our research is establishing valid hearing damage-risk criteria for Army personnel and characterizing the acoustic environments associated with developmental military systems. The present emphasis is the development of the Communications Ear Plug (CEP), a device which substantially enhances communication in noisy environments.

Within the area of biomechanics/crashworthiness, scientists and engineers conduct epidemiological studies and field and laboratory investigations to assess and improve the protective capabilities of life support and personal protective equipment used in armor, aviation, and ground vehicle systems. Current projects in this area include correlation of sitting heights with crash injury risk for Army rotary-wing aircraft mishaps; development of cockpit airbag models for rotary-wing aircraft (see Fig. 2); and anthropometric, cockpit, and aviation life support equipment assessments for women flying Army rotary-wing aircraft.

Scientists are also researching to identify and mitigate the pathological effects of repeated mechanical insult to the operators of current and developmental Army equipment and systems. It defines standards of exposure for repetitive impact so that the design of future systems will minimize this health hazard.

Research Facilities

USAARL has acquired and maintains unique facilities and instrumentation to accomplish its research. For example, USAARL has developed one-of-a-kind research tools to accomplish biomedical/human performance flight research. It has acquired a specially modified UH-60 Helicopter Research Simulator with environmentally controlled cockpit, physiological monitoring, and aircrew flight and aircraft performance measurement system (see Fig. 3). These systems access 134 information channels, sampled and recorded at 30/per second. It reproduces environmental flight conditions within the UH-60 cockpit which simulate arctic, mountainous, jungle, and desert environments. USAARL maintains two rotary-wing and one fixed-wing research aircraft (JUH-60, JUH-1, and C-12). Our helicopters have in-flight measurement systems which monitor and record aviator physical status, flight performance, and aircraft performance in real time. These systems emulate capabilities described for the UH-60 flight simulator. Because of the commonality of these systems, compatible data have been acquired over numerous studies during varying rotary-wing flight scenarios. This database currently contains 1400 megabytes of aviator and aircraft flight performance information. To our knowledge, this is the only aircrew performance database for rotary-wing flight currently in existence.

USAARL also maintains a visual sciences research facility consisting of visual psychophysics, research optical fabrication, and mobile field laboratories to support our basic vision research and our applied research with head- and helmet-mounted visual electro-optical display systems.

USAARL's acoustic/hearing research facilities consist of anechoic and reverberation chambers, audiometric testing chambers, and a mobile testing laboratory. These are used for research to establish noise attenuation criteria and to evaluate hearing-protective devices for soldiers and aviators.

To support its biomechanics/bioengineering research programs, USAARL maintains a helmet impact, retention, and acoustic testing facility as well as the Aviation Life Support Equipment (LSE) Retrieval Program Data Base. This database contains life support equipment perfor-

mance information assessed from equipment retrieved from accidents. These data and the resident test facility permit ongoing equipment evaluations and improvements on current LSE as well as quality assurance testing on developmental items.

USAARL also maintains a Man-rated Multi-axis Ride Simulator to support human tolerance research on repetitive impact (see Fig. 4). This facility provides the unique and singular capability to simulate the ride of any tracked or wheeled vehicle or aircraft. The simulator is linked with multichannel physiological monitoring, biomechanical measurement, and human performance assessment systems.

Future

USAARL continues to pursue its vision to become the DoD Center for Excellence for rotary-wing aeromedical research and consultation on issues related to the support of
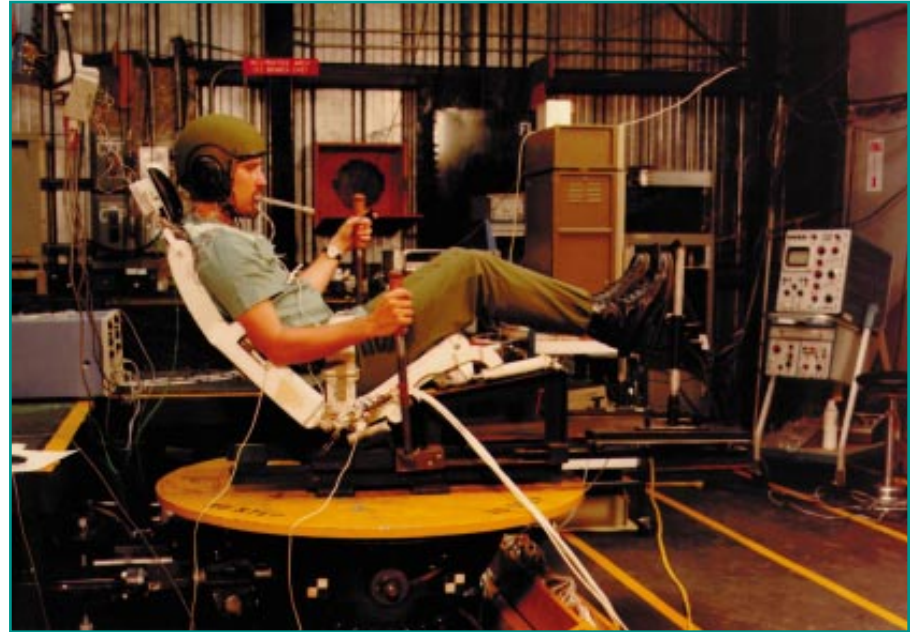
Figure 4. Multi-axis ride simulator (MARS).

the soldier/aviator and optimization of the human-system interface. This vision will be achieved by providing continued quality research and consultation support to our customers; by continuously improving our organization to meet or exceed our customer's expectations; by holding ourselves up as an example of an organization which consistently demonstrates a total commitment to our mission and a dedication to the constant improvement of our products and services; and by being recognized as the Army's focal point for research and expert consultation on issues related to medical, physiological, and psychological support of the soldier/aviator. ●

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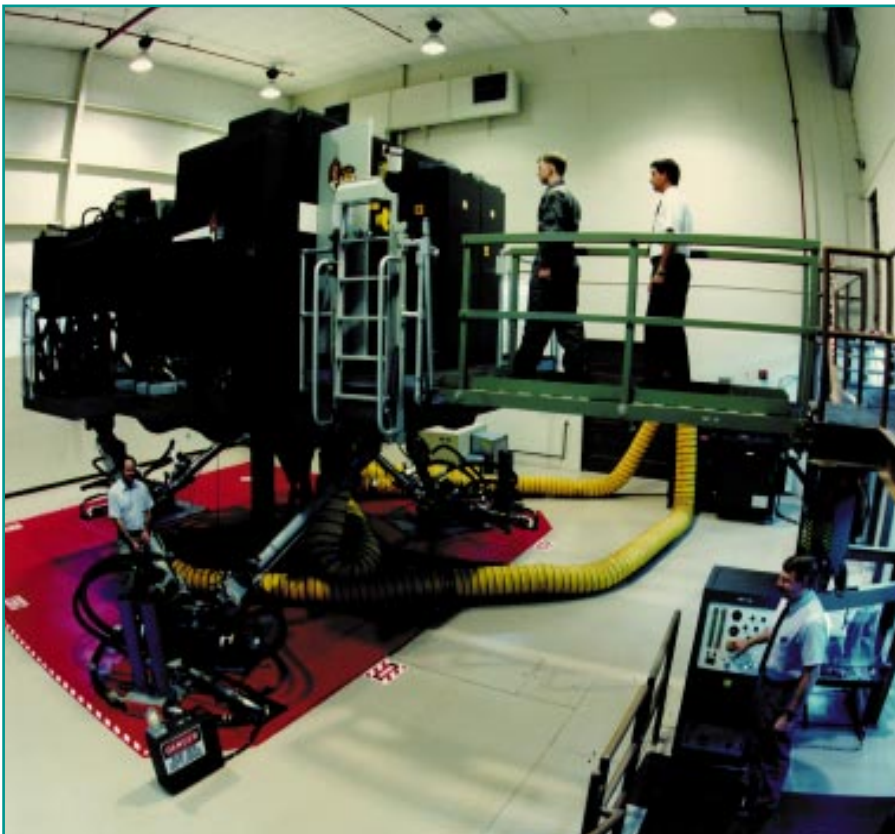
Figure 3. Helicopter research simulator.

A Systematic Way to Assess Compliance with Human Factors Standards

Mary Stearns

Assessing the human factors considerations associated with the design or evaluation of any major new system can be a formidable challenge. To make this more manageable, the Federal Aviation Administration's (FAA) Office of the Chief Scientific and Technical Advisor for Human Factors (AAR-100) and Research, and Special Programs Administration's (RSPA) Volpe National Transportation Systems Center have created a product which will help to enhance the human factors aspects of air traffic control (ATC equipment. The FAA and the Volpe Center developed this product in response to requests from the aviation community.

This product pairs an electronic checklist with a reference text. Using the checklist, a user can rate the performance of equipment against specific criteria, add personal notes, and customize the checklist for specific needs. The checklist contains references linking it to the text, which is a compendium of information on the relationship between human factors and air traffic control operations. This combination of electronic and text format brings to the desk top, and to the lap top, a comprehensive way to identify human factors issues related to air traffic control and a user-friendly way to report results.

Although the checklist and the accompanying text, *Human Factors in the Design and Evaluation of Air Traffic Control Systems*, are geared toward ATC, they can be used to identify human factors issues in any domain, since most of the topics, such as the effects of automation, visual and auditory displays, etc., are applicable to any human-machine interface. Application of the information presented in this handbook will help to minimize the probability of human error in human-system interactions, limit the consequences of these errors, ensure that subsystems are well integrated, and increase the efficiency of human-system performance.

This product covers many topics

including the role of human factors in acquisition, how to develop a human factors plan, the capabilities of humans as information processors, and how to evaluate displays and controls (see Fig. 1). It also discusses issues of particular interest to air traffic control such as the benefits and limitations of automation, methods of workload assessment, the capabilities and limitations of human vision and of the auditory system, time required for information-processing activities, attention, memory and forgetting, problem solving, use of color, flicker, visual and auditory alerts, keyboards, touch screens, trackballs and other input devices, menus, formats for data-entry, and error messages.

The reference handbook and checklist were designed to be used by operations specialists, human factors experts, and system designers. Air traffic control specialists must be involved in every aspect of ATC system development because the human factors challenges, faced in the design and evaluation of air traffic control systems and subsystems, are numerous and complex. These operations specialists help to establish the requirements and play a role in deciding how these systems should be tested before implementation. This important task requires making decisions about the design and operation of displays, controls, and supporting software functions.

The users of this product have primarily been FAA and US military personnel who are involved in the design and evaluation of ATC equipment; the contractors who write requirements for, and manufacture, the systems and subsystems; and an international set of specialists involved in these areas. The FAA has also used a subset of the checklist items in their market survey for the STARS (Standard Terminal Automation Replacement System) program. Unlike previous system buys, where they provided the entire set of specifications and asked the manufacturers to bid on and then build a system to those specifications, the FAA was looking to buy a commer-
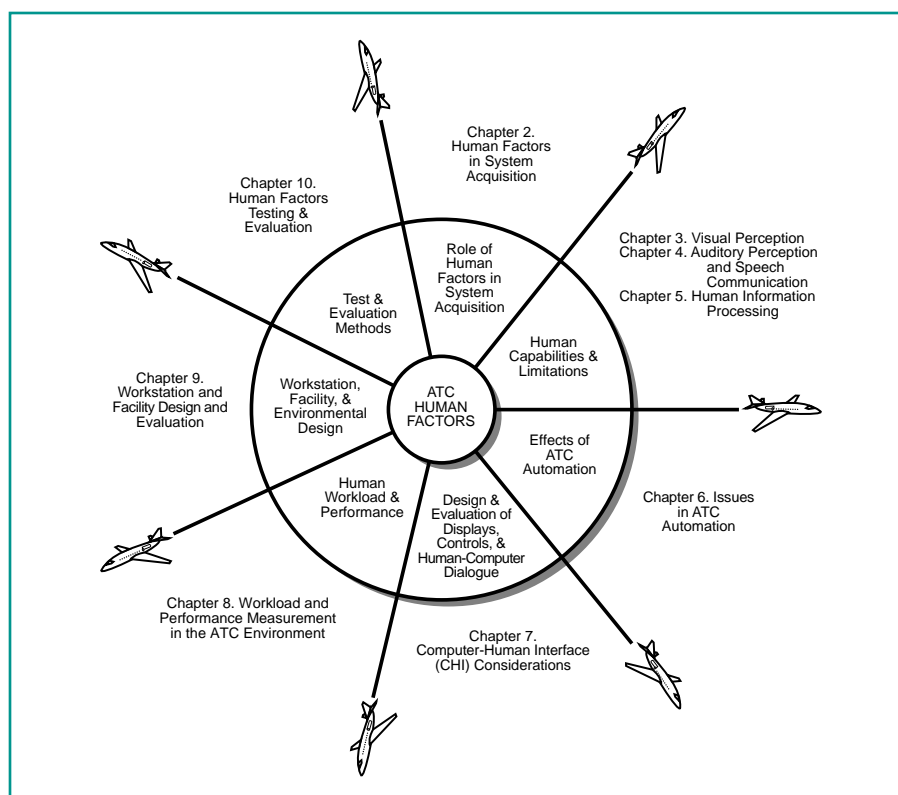

Figure 1. Overview of key human factors topics addressed and chapter where these topics are presented.

cial, off-the-shelf system. The checklist allowed them to evaluate the computer-human interface of each candidate system independently. In this way, the checklist added objectivity and structure to what had historically been a less structured evaluation process.

Use of this product will help to minimize the probability of human error in human-system interactions, limiting the consequences of these errors, and increasing the efficiency of human-system performance. These results support goals identified in the FAA's *National Plan for Civil Aviation Human Factors: An Initiative for Research and Application* (March 1995).

To use the checklist , the following components are needed:
- 386 DX (486 preferred)PC
- Minimum of 8 MB RAM
- 3 1/2 in. diskette drive
- Minimum of 15 MB free hard disk space
- Windows 3.1 or greater
- Windows compatible mouse
- VGA monitor

The checklist and companion text are also available in a hypertext format on CD-ROM.

For more information about *Human Factors in the Design and Evaluation of Air Traffic Control Systems*, contact:

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PhysioKinetics Goniometers: New Technology for Multiple Tracking and Position Measurement Tasks

David C. Johnson

Anew modular technology has been developed to support the need for high-performance relative position measurement of the human body and mechanical apparatus in dynamic applications. Multi-channel sampling rates of up to 1000 Hz each are possible. The PhysioKinetics (PK) goniometer platform is a wearable line of systems and devices providing user-friendly, versatile, high-performance measurement and control inputs at an affordable cost. It is designed for wide applications and unlimited configurations, from ankle position input to head tracking in high performance aircraft during high "G" maneuvers. Analog magnetic sensors provide the basis for this capability. These systems can be configured to measure from 1 to 88 different human joints, and offer low noise susceptibility, reliable data collection, high resolution, instant graphic representation, and many data communication options. A typical PK system is shown in Figure 1.

The development of the PK line of devices started in 1990 with a functional mobility assessment study where workers in different occupations were assessed for their manual range of motion during the typical working day. Intricate measures were required and, as in most cases, there was very little funding for instrumentation. All available systems were either too expensive, inaccurate, large in volume, or slow. The solution was to create a prototype using a focused magnetic field-based transducer, call an EM cell, for non-invasive finger joint measurement. After a short time,

Figure 1. PK-SUIT with two PK-Gloves

colleagues who were analyzing stationary running on a treadmill asked if EM cell technology could be applied to measure knee motion. After building a sensor system for gait analysis, it became obvious that any joint could be measured by some configuration of EM cells.

Over five years of development have gone into optimizing the performance attributes of the EM cell for integration into PK systems.

The goal was to provide a precise, high-resolution sensor system while maintaining low production costs. The result is a line of custom-built products capable of providing versatile, high-performance joint tracking, body position measurement, and object orientation tracking while maintaining a very reasonable cost. A portable system (see Fig. 2) was developed for a recent running optimization experiment. Each custom configuration provides consistent calibrations which are resistant to external magnetic field interference and immune to effects of nearby metal objects (often a problem with magnetic-based tracking systems). The PK platform offers versatility in sensor mounting options as well as hardware configurations. Sensors can be mounted on a variety of objects and surfaces, including garments, garment

Figure 2. Portable measurement of gait motion using full-body PK-SUIT with telemetry.

segments, gloves, straps, helmets, instruments, and the skin. A typical strap-on system, great for wide variations in size among wearers, is shown in Figure 3.

Full body suits are ideal for single wearer measurements of body-position data in a workstation or control/input environment. A PK-SUIT was used in the Armstrong Laboratory Combined Stress Branch DES centrifuge to test the viability of measuring the positions of the upper body of a human subject while at +3.0 Gs. Sixteen channels of joint-position data were recorded at 25 Hz via wireless telemetry to provide information about the crew member's reduced range of motion induced by agile flight.

The hand has the highest concentration of independent joints in the body. To demonstrate the potential for high-integration measurement a PK-GLOVE configuration was built featuring measurement of 21 separate joints. Hand-based controllers can be optimized with this level of integration and a large input capacity. Intelligent activation and monitoring of the sensors minimize cross-talk and enhances channel clarity Alternative inputs can be used for additional controlling functions and/or event

markers. These inputs can be analog signals like temperature, gravity (G), humidity, pressure, and EKG and EMG profiles. Digital signals, such as time pulses, contact switches, and threshold markers, provide the capability for a variety of natural and versatile inputs.

Figure 3. David C. Johnson demonstrating PK products with associate John Schultz wearing PK-SUIT and PK-GLOVE.

Data can be acquired by several means. A personal computer (PC) can be used to directly control the analog digital converter (ADC) and calibration processes. This can be accomplished remotely or through a multiconductor tether. Systems can be configured around any standard (and some not-so-standard) computer platforms. Control can also be accomplished on-board. The data can be sent serially via a coaxial cable or telemetry links; it can also be stored on-board in memory for later downloading.

The PK platform of devices is not limited in range or scope. Control of multi-axis systems and teleoperation

of robotic processes are best done with a virtual reality-like natural interface mechanism. The PK platform can provide a body-position based mechanism that is more effective than buttons, knobs, and levers; it can save training time and make emergency actions easier.

Measurement of hard-to-get data and physiological events is simple with the PK platform. Suited for the virtual reality community, typical uses of the PK-SUIT and the PK-GLOVE are shown in Figure 4 in this telemedicine scenario.

High-level PK systems come with a wide library of software (and the code) for custom expansions, applications, data-logging, visualization, and analysis. The software and code allow the incorporation of your own specific measurement/control goals into your application software, license free. ●

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Figure 4. Telemedicine arrangement using upper-body PK-SUIT and PK-Glove.

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